

THE INVENTION CLAIMED IS:

1. An apparatus adapted to supply substrates to a processing tool, comprising:

a substrate carrier handler adapted to
5 transport a substrate carrier to a first load port of the processing tool, the substrate carrier handler including an end effector adapted to support the substrate carrier; and
a controller coupled to the substrate carrier handler and operative to control the substrate carrier
10 handler such that the end effector of the substrate carrier handler disengages the substrate carrier from a substrate carrier conveyor while the substrate carrier is in motion and being transported by the substrate carrier conveyor.

15 2. The apparatus of claim 1 wherein the controller is operative to control the substrate carrier handler such that the end effector of the substrate carrier handler substantially matches a motion of the substrate carrier during at least a portion of the disengagement of
20 the substrate carrier from the substrate carrier conveyor.

3. The apparatus of claim 2 wherein the controller is operative to control the substrate carrier handler such that the end effector of the substrate carrier
25 handler substantially matches a velocity of the substrate carrier during at least a portion of the disengagement of the substrate carrier from the substrate carrier conveyor.

4. The apparatus of claim 3 wherein the
30 controller is operative to control the substrate carrier handler such that the end effector of the substrate carrier handler substantially matches a speed and position of the substrate carrier in a horizontal direction during at least a portion of the disengagement of the substrate carrier from
35 the substrate carrier conveyor.

5. The apparatus of claim 1, wherein the controller is further operative to control the substrate carrier handler such that the end effector is moved so as to remain adjacent and below the substrate carrier as the substrate carrier is being transported by the substrate carrier conveyor.

6. The apparatus of claim 5, wherein the controller is further operative to control the substrate carrier handler such that the end effector of the substrate carrier handler is raised, while being moved in a horizontal direction, so as to disengage the substrate carrier from the substrate carrier conveyor.

7. The apparatus of claim 1 wherein the controller is further operative to control the substrate carrier handler such that the end effector contacts the substrate carrier with at least one of a substantially zero velocity or less and a substantially zero acceleration or less in a vertical direction to disengage the substrate carrier from the substrate carrier conveyor.

8. The apparatus of claim 7 wherein the controller is further operative to control the substrate carrier handler such that the end effector contacts the substrate carrier with substantially zero acceleration or less in a horizontal direction of travel of the substrate carrier conveyor to disengage the substrate carrier from the substrate carrier conveyor.

9. The apparatus of claim 1, wherein the substrate carrier handler includes a vertical guide and a horizontal guide coupled to the vertical guide.

10. The apparatus of claim 9, wherein:
the substrate carrier handler includes a pair
of vertical guides;
the horizontal guide is mounted for vertical
5 movement along the vertical guides; and
the end effector is mounted for horizontal
movement along the horizontal guide.
11. The apparatus of claim 1, wherein the
10 substrate carrier handler is adapted to move the end
effector to at least an elevation at which the substrate
carrier conveyor transports substrate carriers.
12. The apparatus of claim 1, wherein the first
15 load port comprising a first docking station, and further
comprising at least one other docking station vertically
disposed relative to the first docking station.
13. The apparatus of claim 12, further comprising
20 two columns of docking stations, the first docking station
being included in one of the two columns of docking
stations.
14. The apparatus of claim 1, further comprising
25 at least one sensor coupled to the controller and adapted to
indicate a position of a component of the substrate carrier
conveyor.
15. The apparatus of claim 1, wherein the
30 substrate carrier is a single substrate carrier.
16. The apparatus of claim 1, wherein the end
effector of the substrate carrier handler includes a
horizontally oriented platform having a plurality of
35 kinematic features.

17. The apparatus of claim 1, wherein the conveyor is positioned above the substrate carrier handler.

5 18. The apparatus of claim 1, further comprising at least one storage shelf adapted to store a substrate carrier;

 wherein the substrate carrier handler is adapted to transport a substrate carrier between the first
10 load port and the at least one storage shelf.

 19. The apparatus of claim 1 wherein the controller is further operative to control the substrate carrier handler such that the end effector of the substrate
15 carrier handler transfers the substrate carrier to the substrate carrier conveyor while the substrate carrier conveyor is in motion.

 20. The apparatus of claim 19 wherein the controller is operative to control the substrate carrier handler such that the end effector of the substrate carrier handler substantially matches a motion of the substrate carrier conveyor during at least a portion of the transfer
20 of the substrate carrier to the substrate carrier conveyor.

25 21. The apparatus of claim 20 wherein the controller is operative to control the substrate carrier handler such that the end effector of the substrate carrier handler substantially matches a velocity of the substrate carrier conveyor during at least a portion of the transfer
30 of the substrate carrier to the substrate carrier conveyor.

 22. The apparatus of claim 21 wherein the controller is operative to control the substrate carrier handler such that the end effector of the substrate carrier
35 handler such that the end effector of the substrate carrier

handler substantially matches a speed of the substrate carrier conveyor in a horizontal direction during at least a portion of the transfer of the substrate carrier to the substrate carrier conveyor.

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23. The apparatus of claim 19 wherein the controller is further operative to control the substrate carrier handler such that the substrate carrier contacts the substrate carrier conveyor with at least one of a substantially zero velocity or less and a substantially zero acceleration or less in a vertical direction to load the substrate carrier onto the substrate carrier conveyor.

24. The apparatus of claim 23 wherein the controller is further operative to control the substrate carrier handler such that the substrate carrier contacts the substrate carrier conveyor with substantially zero acceleration or less in a horizontal direction of travel of the substrate carrier conveyor to load the substrate carrier onto the substrate carrier conveyor.

25. An apparatus adapted to supply substrates to a processing tool, comprising:

a substrate carrier handler adapted to transport a substrate carrier to a first load port of the processing tool, the substrate carrier handler including:
a vertical guide;
a horizontal guide coupled to the vertical guide; and
an end effector adapted to support the substrate carrier and to move vertically relative to the vertical guide and horizontally relative to the horizontal guide; and
a controller coupled to the substrate carrier handler and operative to control the substrate carrier

handler such that the end effector of the substrate carrier handler disengages the substrate carrier from a substrate carrier conveyor positioned adjacent the substrate carrier handler.

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26. The apparatus of claim 25 wherein the substrate carrier handler includes a pair of vertical guides and wherein:

the horizontal guide is adapted to move
10 vertically along the pair of vertical guides; and
the end effector is adapted to move
horizontally along the horizontal guide.

27. The apparatus of claim 25 wherein the
15 controller is further operative to control the substrate carrier handler such that the end effector of the substrate carrier handler disengages the substrate carrier from the substrate carrier conveyor while the substrate carrier is in motion and being transported by the substrate carrier
20 conveyor.

28. A method of transferring a substrate carrier, comprising:

conveying the substrate carrier on a
25 substrate carrier conveyor positioned adjacent a substrate loading station that includes a substrate carrier handler adapted to transport the substrate carrier to a load port of a processing tool; and
employing an end effector of the substrate
30 carrier handler of the substrate loading station to disengage the substrate carrier from the substrate carrier conveyor while the substrate carrier is in motion and being transported by the substrate carrier conveyor.

29. The method of claim 28, wherein employing the end effector of the substrate carrier handler of the substrate loading station to disengage the substrate carrier comprises, moving the end effector so as to substantially match a motion of the substrate carrier during at least a portion of the disengagement of the substrate carrier from the substrate carrier conveyor.

30. The method of claim 29, wherein moving the end effector so as to substantially match a motion of the substrate carrier comprises moving the end effector so as to substantially match a velocity of the substrate carrier during at least a portion of the disengagement of the substrate carrier from the substrate carrier conveyor.

31. The method of claim 29, wherein moving the end effector so as to substantially match a motion of the substrate carrier comprises moving the end effector so as to substantially match a speed and position of the substrate carrier along a horizontal direction during at least a portion of the disengagement of the substrate carrier from the substrate carrier conveyor.

32. The method of claim 28, wherein disengaging the substrate carrier includes raising the end effector to contact a bottom of the substrate carrier.

33. The method of claim 28, wherein disengaging the substrate carrier comprises moving the end effector along a horizontal guide that is part of the substrate carrier handler.

34. The method of claim 33, wherein disengaging the substrate carrier includes raising the horizontal guide

along at least one vertical guide that is part of the substrate carrier handler.

35. The method of claim 28, wherein disengaging
5 the substrate carrier includes moving the end effector to an elevation at which the substrate carrier is conveyed.

36. The method of claim 28 wherein employing the
end effector of the substrate carrier handler of the
10 substrate loading station to disengage the substrate carrier comprises contacting the substrate carrier with the end effector with at least one of a substantially zero velocity or less and a substantially zero acceleration or less in a vertical direction to disengage the substrate carrier from
15 the substrate carrier conveyor.

37. The method of claim 36 wherein employing the
end effector of the substrate carrier handler of the
substrate loading station to disengage the substrate carrier
20 comprises contacting the substrate carrier with the end effector with substantially zero acceleration or less in a horizontal direction of travel of the substrate carrier conveyor to disengage the substrate carrier from the substrate carrier conveyor.

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38. The method of claim 28, wherein conveying the substrate carrier includes conveying the substrate carrier above the substrate loading station.

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39. The method of claim 28 further comprising employing the end effector to transfer the substrate carrier to the substrate carrier conveyor while the substrate carrier conveyor is in motion.

40. The method of claim 39, wherein employing the end effector to transfer the substrate carrier to the substrate carrier conveyor comprises moving the end effector so as to substantially match a motion of the substrate carrier conveyor during at least a portion of the transfer of the substrate carrier to the substrate carrier conveyor.

41. The method of claim 40, wherein moving the end effector so as to substantially match a motion of the substrate carrier conveyor comprises moving the end effector so as to substantially match a velocity of the substrate carrier conveyor.

42. The method of claim 40, wherein moving the end effector so as to substantially match a motion of the substrate carrier conveyor comprises moving the end effector so as to substantially match a speed of the substrate carrier conveyor along a horizontal direction.

43. The method of claim 39, wherein transferring the substrate carrier to the substrate carrier conveyor includes lowering the end effector to hand off the substrate carrier to a carrier engagement member of the substrate carrier conveyor.

44. The method of claim 43, wherein the end effector is lowered by lowering a horizontal guide.

45. The method of claim 43, wherein transferring the substrate carrier to the substrate carrier conveyor includes moving the end effector to an elevation at which the substrate carrier conveyor transports substrate carriers.

46. The method of claim 39 wherein employing the end effector to transfer the substrate carrier to the substrate carrier conveyor while the substrate carrier conveyor is in motion comprises contacting the substrate carrier conveyor with the substrate carrier with at least one of a substantially zero velocity or less and a substantially zero acceleration or less in a vertical direction to load the substrate carrier onto the substrate carrier conveyor.

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47. The method of claim 46 wherein employing the end effector to transfer the substrate carrier to the substrate carrier conveyor while the substrate carrier conveyor is in motion comprises contacting the substrate carrier conveyor with the substrate carrier with substantially zero acceleration or less in a horizontal direction of travel of the substrate carrier conveyor to load the substrate carrier onto the substrate carrier conveyor.

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48. A method of transferring a substrate carrier to a substrate loading station, comprising:

conveying the substrate carrier on a substrate carrier conveyor positioned adjacent to the substrate loading station, the substrate loading station having:

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a substrate carrier handler adapted to transport the substrate carrier to a first load port of a processing tool, the substrate carrier handler including:

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a vertical guide;
a horizontal guide coupled to the vertical guide; and

an end effector adapted to support the substrate carrier and to move vertically relative to the

vertical guide and horizontally relative to the horizontal guide; and

employing the end effector of the substrate carrier handler of the substrate loading station to
5 disengage the substrate carrier from the substrate carrier conveyor.

49. The method of claim 48 wherein the substrate carrier handler includes a pair of vertical guides and
10 wherein:

the horizontal guide is adapted to move vertically along the pair of vertical guides; and

the end effector is adapted to move horizontally along the horizontal guide.

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50. The method of claim 48 wherein employing the end effector to disengage the substrate carrier from the substrate carrier conveyor comprises disengaging the substrate carrier from the substrate carrier conveyor while
20 the substrate carrier is in motion.

51. An apparatus adapted to supply substrates to a processing tool, comprising:

a substrate carrier handler adapted to
25 transport a substrate carrier to a first load port of the processing tool, the substrate carrier handler including an end effector adapted to support the substrate carrier; and
a controller coupled to the substrate carrier handler and operative to control the substrate carrier
30 handler to:

move the end effector of the substrate carrier handler in a horizontal direction to substantially match a motion of the substrate carrier as the substrate carrier is being transported by a substrate carrier
35 conveyor;

raise the end effector to engage the
substrate carrier and to disengage the substrate carrier
from the substrate carrier conveyor; and
transport the substrate carrier to the
5 first load port.

52. The apparatus of claim 51, wherein the
controller is operative to control the substrate carrier
handler so as to decelerate the horizontal motion of the end
10 effector after the raising step.

53. The apparatus of claim 52, wherein the
controller is operative to control the substrate carrier
handler so as to lower the end effector after the
15 decelerating step.

54. The apparatus of claim 53, wherein the
controller is operative to control the substrate carrier
handler so as to accelerate the horizontal motion of the end
20 effector after the decelerating step and before the lowering
step.

55. The apparatus of claim 53, wherein the
controller is operative to control the substrate carrier
25 handler so as to halt the horizontal motion of the end
effector after the lowering step.

56. The apparatus of claim 51, wherein the
controller is operative to control the substrate carrier
30 handler so as to hand off the substrate carrier to the first
load port after the transporting step.

57. A method of operating a substrate carrier
handler, comprising:

moving an end effector of the substrate carrier handler in a horizontal direction to substantially match motion of the substrate carrier as the substrate carrier is being transported by a substrate carrier

5 conveyor;

raising the end effector to engage the substrate carrier and to disengage the substrate carrier from the substrate carrier conveyor; and

10 transporting the substrate carrier to a load port.

58. The method of claim 57, wherein the moving step includes moving the end effector along a horizontal guide of the substrate carrier handler.

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59. The method of the 57, further comprising decelerating the horizontal motion of the end effector after the raising step.

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60. The method of claim 59, further comprising lowering the end effector after the decelerating step.

25 61. The method of claim 60, further comprising accelerating the horizontal motion of the end effector after the decelerating step and before the lowering step.

30 62. The method of claim 60, further comprising halting the horizontal motion of the end effector after the lowering step.

63. The method of claim 57, further comprising handing off the substrate carrier to the load port after the transporting step.

64. The method of claim 57, wherein the raising step includes raising a horizontal guide of the substrate carrier handler.

5 65. The apparatus of claim 1 wherein the controller is operative to automatically retract the end effector from the conveyor in response to a predetermined event.

10 66. The apparatus of claim 65 wherein the predetermined event comprises at least one of a power failure and an emergency shutdown.

15 67. The apparatus of claim 25 wherein the controller is operative to automatically retract the end effector from the conveyor in response to a predetermined event.

20 68. The apparatus of claim 67 wherein the predetermined event comprises at least one of a power failure and an emergency shutdown.

25 69. The method of claim 28 further comprising automatically retracting the end effector from the conveyor in response to a predetermined event.

30 70. The method of 69 wherein the predetermined event comprises at least one of a power failure and an emergency shutdown.

35 71. The apparatus of claim 51 wherein the controller is operative to automatically retract the end effector from the conveyor in response to a predetermined event.

72. The apparatus of claim 71 wherein the predetermined event comprises at least one of a power failure and an emergency shutdown.

5 73. The method of claim 48 further comprising automatically retracting the end effector from the conveyor in response to a predetermined event.

10 74. The method of 73 wherein the predetermined event comprises at least one of a power failure and an emergency shutdown.

15 75. The method of claim 57 further comprising automatically retracting the end effector from the conveyor in response to a predetermined event.

20 76. The method of 75 wherein the predetermined event comprises at least one of a power failure and an emergency shutdown.

27. An apparatus adapted to supply substrates to a processing tool, comprising:

25 a substrate carrier handler adapted to transport a substrate carrier to a first load port of the processing tool, the substrate carrier handler including an end effector adapted to support the substrate carrier; and
 a controller coupled to the substrate carrier handler and operative to control the substrate carrier handler such that the end effector of the substrate carrier handler disengages the substrate carrier from a substrate carrier conveyor while the substrate carrier is in motion
30 by:

 determining a speed of the substrate carrier conveyor;
35 determining a first motion profile for

the end effector based on the speed of the substrate carrier conveyor; and

employing the first motion profile to control motion of the end effector during at least a portion of disengagement of the substrate carrier from the substrate carrier conveyor.

78. The apparatus of claim 77 wherein the controller is further operative to abort disengagement of the substrate carrier from the substrate carrier conveyor if the speed of the substrate carrier conveyor is outside of a predetermined range.

79. The apparatus of claim 77 wherein the controller is further operative to control the substrate carrier handler such that the end effector of the substrate carrier handler transfers the substrate carrier to the substrate carrier conveyor while the substrate carrier conveyor is in motion by:

determining a second motion profile for the end effector based on substrate carrier conveyor speed; and employing the second motion profile to control motion of the end effector during at least a portion of transfer of the substrate carrier to the substrate carrier conveyor.

80. The apparatus of claim 79 wherein the controller is further operative to abort transfer of the substrate carrier to the substrate carrier conveyor if substrate carrier conveyor speed is outside of a predetermined range.

81. A method of transferring a substrate carrier, comprising:

conveying the substrate carrier on a
substrate carrier conveyor positioned adjacent a substrate
loading station that includes a substrate carrier handler
adapted to transport the substrate carrier to a load port;
5 determining a speed of the substrate carrier
conveyor;

determining a first motion profile for an end
effector of the substrate carrier handler based on the speed
of the substrate carrier conveyor; and

10 employing the first motion profile to control
motion of the end effector during at least a portion of
disengagement of the substrate carrier from the substrate
carrier conveyor.

15 82. The method of claim 81 further comprising:
determining a second motion profile for the
end effector based on substrate carrier conveyor speed; and
employing the second motion profile to
control motion of the end effector during at least a portion
20 of transfer of the substrate carrier to the substrate
carrier conveyor.

83. A computer program product adapted to control
disengagement of a substrate carrier from a substrate
25 carrier conveyor positioned adjacent a substrate loading
station that includes a substrate carrier handler adapted to
transport the substrate carrier to a load port, the computer
program product comprising:

a medium readable by a computer, the computer
30 readable medium having computer program code adapted to:
determine a speed of the substrate
carrier conveyor;

determine a first motion profile for an
end effector of the substrate carrier handler based on the
35 speed of the substrate carrier conveyor; and

employ the first motion profile to control motion of the end effector during at least a portion of disengagement of the substrate carrier from the substrate carrier conveyor.

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84. The computer program product of claim 83 further comprising computer program code adapted to:

determine a second motion profile for the end effector based on substrate carrier conveyor speed; and

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employ the second motion profile to control motion of the end effector during at least a portion of transfer of the substrate carrier to the substrate carrier conveyor.

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85. An apparatus adapted to supply substrates to a processing tool, comprising:

an end effector adapted to support a substrate and transport the substrate to a first load port of the processing tool; and

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a controller coupled to the end effector and operative to control the end effector such that the end effector disengages the substrate from a moving conveyor while the substrate is in motion and being transported by the conveyor.

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86. The apparatus of claim 85 wherein the controller is further operative to control the end effector such that the end effector transfers the substrate to the conveyor while the conveyor is in motion.

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87. A method of transferring a substrate, comprising:

conveying the substrate on a conveyor positioned adjacent a substrate loading station that

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includes an end effector adapted to support the substrate

and to transport the substrate to a load port of a processing tool; and

employing the end effector of the substrate loading station to disengage the substrate from the conveyor while the substrate is in motion and being transported by the conveyor.

88. The method of claim 87 further comprising employing the end effector to transfer the substrate to the conveyor while the conveyor is in motion.

89. An apparatus comprising:
a substrate carrier handler adapted to transport a substrate carrier to a first load port of a processing tool, the substrate carrier handler including an end effector adapted to support the substrate carrier; and
a controller coupled to the substrate carrier handler and operative to control the substrate carrier handler such that the end effector of the substrate carrier handler transfers the substrate carrier to a substrate carrier conveyor while the substrate carrier conveyor is in motion.

90. The apparatus of claim 1 wherein the controller is further operative to control the substrate carrier handler such that the end effector contacts the substrate carrier with substantially zero velocity or less in a vertical direction to disengage the substrate carrier from the substrate carrier conveyor.